the sanitary aspects of the beds are noticed. In the map the index of colours is grouped in three series, clayey, gravelly and sandy, with Alluvium detached at the top, and Chalk at the bottom.

In the rest of the memoir a purely sanitary arrangement is adopted, under four heads, the first being that of the sub-soil with reference to sites for houses (pp. 27–32). The way in which not only the character of the beds, but also their thickness, position, and mutual relations affect the suitability of ground for building-purposes is enforced, and the causes of contamination of porous sub-soils are discussed: even gardens are not neglected.

Secondly, water-supply and drainage are treated (pp. 33–39). After noticing the supply of London, the question of rural water-supply is taken, the causes of contamination of shallow wells and the danger of "dead wells," used as receptacles for sewage, &c., being described. Then we have sanitary considerations in regard to the situation and surroundings of houses (pp. 40–45), under which head subjects other than geologic are referred to, such as surface-drainage, fog, sunshine, rain, wind, floods.

The troublesome question of cemeteries fittingly comes last (pp. 46–48), and the author concludes that "an isolated tract of elevated ground, where sands and sandy loams, or sandy and loamy gravel, of considerable thickness, rest on clay also of considerable thickness, offers the most desirable site," which, however, is qualified by the addition that "probably a sandy and calcareous loam is the best material for a graveyard." However, the difficulty is to get such desirable sites! The fitting conclusion is a list of the cemeteries in and near London, with the beds on which they are placed, by means of which people who are thoughtful of their latter end can select the geologic formation in which they would like to be buried.

The long index (ten pages), is really more than an index. It is not limited to giving the pages of reference; but also notes, by figures in another type, the height of the various places above Ordnance datum, and, by means of letters, the beds on which the places are—an ingenious and useful novelty.

Although this is the first Geological Survey memoir devoted to sanitary matters, it should be remembered that stores of information that is useful from a sanitary point of view are to be found in many of those memoirs, especially as regards wells and water-supply.

This work should have a ready sale, as it is written in such a way as to be useful to the ordinary inquirer, and of interest to any intelligent reader; but the price (*2s. 6d.*) is rather high, presumably on account of the map. It is to be hoped that the author may ere long have to prepare a new and enlarged edition, and that the success of the present venture may lead to other work of the same sort being undertaken.

W. WHITAKER.

PROFS. C. RUNGE AND F. PASCHEN'S RESEARCHES ON THE SPECTRA OF OXYGEN, SULPHUR, AND SELENIUM.[1]

In the above paper Profs. Runge and Paschen have extended their important investigations to the spectra of oxygen, sulphur and selenium, and have discovered in the low temperature spectra of these elements a number of series which are very similar to those previously found for other elements. The principal characteristics of these series are too well known to need any further explanation; they may be represented by Kayser and Runge's original formula,

$$N = A - \frac{B}{n^2} - \frac{C}{n^4},$$

where N is the wave frequency and n takes up the values 3, 4, 5 . . . for the different lines of the same series. In the present cases n^4 may be with advantage replaced by n^3. We may with equal accuracy take Rydberg's formula,

$$N = A - B(n + \mu)^{-2},$$

where A, B, μ are the three constants. In the spectrum of oxygen which goes by the name of "compound line spectrum," and which Piazzi Smyth has shown to be chiefly made up of close triplets, Runge and Paschen show that these triplets arrange themselves in two series, having approximately the same convergence frequency. The difference in the curve numbers of the components being the same for each triplet, they have all the characteristics of the "Nebenserien" or "associated series," as I propose to call them, because they always occur in groups of two. The formulæ for the strongest lines of the triplets in Rydberg's form is

1st assoc. series: $23207,96 - 110396\,(n - 0{\cdot}02148)^{-2}$
2nd ,, ,, $23200,63 - 109011\,(n - 0{\cdot}24127)^{-2}$

Rydberg has given a law according to which the principal series may be calculated from the associated series, with sufficient approximation to identify the lines belonging to it in the present instance. Only two triplets belonging to it have been found; the first in the extreme red has a wave-length of 7776 for its strongest lines, and the second, photographed by Runge and Paschen for the first time, has a wave-length 3948. In addition to the triplets, the authors have discovered a number of doublets which can also be grouped into two associated series, having the equations

$$21205,56 - 109366,7\,(n - 0{\cdot}16191)^{-2}$$
$$21211,11 - 110346,7\,(n - 0{\cdot}01093)^{-2}$$

and the principal series belonging to this group is probably represented by two lines at wave-lengths 4368, 5, and 3692, 6, the former being one of the strongest lines of the compound line spectrum.

The result of this investigation of the oxygen spectrum is, that it shows two sets of associated series similar to that found in the case of helium, and that therefore the spectroscopic evidence that helium is a mixture of two gases no longer holds. There is very little doubt that the oxygen spectrum is represented among the Fraunhofer lines; almost conclusive evidence in favour of this being given by the first triplet of the principal series, which falls at 7776 in a portion of the solar spectrum which is comparatively free from lines. The beautiful photographs of Higg show at this place a triplet the components of which have exactly the right difference in frequency.

Profs. Runge and Paschen also investigated the spectra of sulphur and selenium, and discovered spectra which correspond to the compound line spectrum of oxygen. The spectra consist chiefly of triplets which may be arranged in a group of associated series; and there are also indications of the existence of two principal series in each case. The authors apparently considered these spectra as due to the elements, but they have only been able to obtain them in the presence of oxygen. Further investigation is therefore required to show that they are not really oxide spectra. Should this prove to be the case it would be a matter of some importance and great interest, for it would show that we must consider the compound line spectrum of oxygen as due to a compound molecule, an "oxide of oxygen" similar in constitution to the oxides of sulphur and selenium which give the analogous spectra.

In conclusion, I may add a few remarks as to the relative merits of Rydberg's and Kayser and Runge's equations. The greater simplicity in form of

$$N = A - \frac{B}{n^2} - \frac{C}{n^4}$$

adopted by Kayser and Runge, and the ease with which the constants may be calculated would, independently of

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[1] *Wiedemann's Annalen*, vol. lxi. p. 641.

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other considerations, lead us to give the preference to this form. The advantage is not, however, great, and disappears when we have to distinguish cases where we must substitute n^3 for n^4. The reason why I prefer Rydberg's form at present lies in the fact that it adapts itself better to bring out the regularities as well as the irregularities of distribution of the lines independently of any special form of equation. To show this we may write Rydberg's equation in the form

$$\frac{n+\mu}{\sqrt{B}} = \frac{1}{\sqrt{A-N}}.$$

The convergence frequency, A, may be determined by some graphical process if a sufficient number of lines have been observed, and the law of formation of a spectroscopic series may therefore be expressed as follows:

The inverse square roots of the difference between the convergence frequency and the frequency of successive lines are very approximately in arithmetical progression. If we wish to determine how far any series conforms to this law, we may in the first place calculate the right-hand side of the above expression with some approximate value of A. Systematic deviations from arithmetical progression may then be corrected by a small change, δA producing a difference $\frac{\delta A}{\sqrt{(A-N)^3}}$ in the numbers. But it will nearly always be found that there are some outstanding deviations which cannot be corrected for in this way. The value of B is found at once from the arithmetical progression successive numbers differing by $\frac{1}{\sqrt{B}}$. I have found this method of testing the series and calculating the constants very useful, and hope on some other occasion to return to it.

ARTHUR SCHUSTER.

UNDULATIONS IN LAKES AND INLAND SEAS DUE TO WIND AND ATMOSPHERIC PRESSURE.

IT is generally known that considerable variation takes place in the level of the surface of the water in lakes and inland seas owing to the effect of the wind in gales and during stormy weather. The minor undulations which occur at more regular intervals have not attracted the same observation, and the cause of these is still a matter of some uncertainty. In the large lakes in America, fishermen and boatmen have learnt to regard these undulations as storm warnings; and on the coasts of Europe, the rollers which break on the shore in calm weather are looked upon as indicative of a coming storm. Thus, in the Bay of Biscay frequently during the autumn and winter in calm weather a heavy sea gets up and rolls in on to the coast four-and-twenty hours before the gale which causes it arrives, and of which it is the prelude. In this case the wave action, generated on the other side of the Atlantic by the wind, travels at much greater rate than that of wind, and thus gives timely warning of the coming storm. So also on the opposite side of the Atlantic, on the coast between North Carolina and Cape Hatteras, the currents, which are there largely governed by the wind, begin to run strongly several hours in advance of the wind which causes them. In summer a change of the current from north-east to south-west is always taken as a true indication of an approaching north-east wind.

The effect of gales on tideless seas and lakes is so marked as to cause frequently considerable inconvenience and anxiety to mariners. Thus, in the Caspian Sea a gale will raise the water on one side 6 feet and depress it on the other as much, making a total difference of level of 12 feet.[1] In the Baltic easterly gales will alter the level upwards of 8 feet. In Lake Erie[1] depressions and elevations of from 2 to 4 feet are common, while occasionally heavy gales have produced a difference of level of upwards of 15 feet. Almost invariably about the time of the spring equinox strong gales occur from the east, raising the water from 4 to 6 feet at the west end of the lake, and depressing it to a similar extent at the east end, making a total difference of from 8 to 12 feet. About the time of the autumn equinox gales from the west lower the water 7 to 8 feet at the west side, and raise it 5 to 8 feet at the east end, making a difference from the normal level of from 12 to 16 feet. An illustration is given by Mr. Blunt, the engineer, who reported on the subject for the United States Commission as to the way in which the navigation of the lakes and of the rivers connected with them is affected by storms acting on the surface of the water. A steamer which had to make a trip down the river found the water at the pier from which she started, five miles from the mouth, had receded to 7½ feet below the normal level. In the river, flats were showing where a few days before they had found 8 feet of water. In the middle of the bay a large dredger was aground where there ought to have been 17 feet of water.

In addition to these larger oscillations, there are also minor undulations which occur at varying intervals, the largest period for a complete oscillation not exceeding half an hour, and the alteration in the level of the water not more than from three to four inches. The phenomena had been noted by Duillier on the Swiss Lakes in the middle of the last century, the name locally given to them being *Seiches*. In 1804 Vaucher also investigated the matter and published an account of his researches, his experience being that they were common to all the lakes; that they recurred at all seasons of the year, but most frequently in spring and autumn, the greatest oscillation, however, occurring in the summer; and that the intervals between the oscillations did not exceed twenty to twenty-five minutes, and more frequently less.

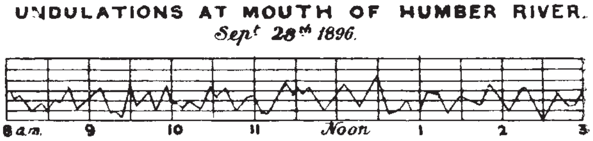

FIG. 1.

A few years since the writer had occasion to investigate the oscillations which took place in one of the Norfolk Broads, and which were taken as showing that the water was tidal. It was found that variations of from half an inch to two and three inches in the level of the water took place periodically, and at times when the atmosphere was calm. Observations spread over a considerable time proved that these undulations were not coincident with the rise and fall of the tides, and that they had no direct connection with the ebb and flow in the river with which this Broad was connected.

The character of the undulations on Lake Superior has been investigated by Mr. Napier Denison, and the results communicated to the Canadian Institute in February 1897, in a paper entitled "The great lakes as a sensitive barometer." For the purpose of tracing these curves Mr. Denison had two self-recording gauges constructed, one being fixed at the mouth of the river Humber, and the other at the Burlington Canal. The results of one day's reading at the mouth of the Humber are shown in Fig. 1, which is sufficient generally to illustrate the result of the readings obtained, and as showing the rapid undulations upon the lakes during light winds and fine weather preceding a severe storm. (The divisions in the above

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[1] "Tidal Rivers," chap. v. (Longmans, Green, and Co.).

[1] Report of Deep Waterways Commission, U.S.A. (Washington, 1897).

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